Conservation monitoring of three management treatments for public understanding of meadow management

Article (Published Version)

Conservation Monitoring of Three Management Treatments for Public Understanding of Meadow Management

Margaret Pilkington
Centre for Continuing Education, University of Sussex,
Falmer, Brighton, UK, BN1 9RG

Summary

In this paper the declining habitat of flower-rich grassland on neutral soil (MG5a) is used as an example to show how non-classical ecological experiments set in a real-life situations can provide answers to practical questions and thus contribute directly to achieving biodiversity targets. Such biodiverse grassland is vanishing at an alarming rate from the farming sector, but remains as small areas within many community sites. Here it is unlikely to be managed appropriately unless the effect of different management treatments can be demonstrated to the local community and to those responsible for management decisions.

This paper describes such a demonstration set up on a community site in Sussex. Three different treatments were imposed on the field in a way that was practical to apply and easily understood, but since this precluded replication of treatments the demonstration should be regarded as an example of pro-active conservation monitoring rather than a field trial. Discriminant analysis was used to show pre-treatment similarities between areas together with change of direction following treatments, supporting conclusions drawn from unreplicated analysis of variance models. Aftermath grazing led to a higher percentage cover of wildflowers in the sward and an annual application of organic fertiliser led to a lower percentage cover of wildflowers. Varying the timing of the hay cut made no significant difference.

Introduction

Lowland neutral grassland occurs on moist mineral soils with pH between 4.5 and 6.5 (Rodwell,1992, p.21). Such grassland is widespread, but little studied (Vickery *et al.*, 2001). Most of it is now agriculturally improved, with little conservation interest. This paper is concerned with the remaining unimproved species-rich part, represented by National Vegetation Classification type *Cynosurus cristatus – Centaurea nigra* (MG5) grassland (Rodwell, 1992). Recent estimates suggest that less than 4,000 hectares remain in Britain and that much of this is in small scattered patches (Sussex Wildlife Trust, 1995). It continues to be lost from the farming sector (Pilkington 1999 Sussex survey, unpublished) which lends an urgency to the conservation of all remaining areas including the small scattered patches which are often within urban greenspaces and managed by local councils without specialist knowledge.

One such site, Bedelands Farm Local Nature Reserve, occurs on the edge of the conurbation of Burgess Hill in West Sussex and illustrates the problems well. It contains several flower-rich meadows which although identified in Phase 1 Habitat Surveys, were suffering from *ad hoc* management by the local council. This was partly due to lack of understanding, council officials being more used to managing playing fields than flower-rich grassland, but also there were potential problems with grazing animals and dog-walkers, and the added difficulty of sporadic vandalism. A clear demonstration of the effect of different management options on the wildflowers was needed if more appropriate management was to be introduced, which was likely to be more costly and possibly less acceptable to the general public. Once set up as a living exhibition such a demonstration could be used to inform other councils as well as countryside stewardship schemes through agencies such as the Farming and Wildlife Advisory Group (FWAG). Finally scientific monitoring of the demonstration would enable the results to be disseminated more widely throughout the country by publication in a conservation journal.

Cynosurus cristatus – Centaurea nigra grasslands were traditionally managed as hay meadows with an annual hay cut, autumn- and winter-grazing, and manuring by stock (Rodwell, 1992). In the lowlands, hay meadows were left ungrazed from February or March and were cut for hay between June and August (Sutherland and Hill, 1995). This should provide a good starting point for appropriate management today, but in the past meadows were cut at different times over the summer depending on the particular weather conditions in any one year (Smith and Jones, 1991). In a community setting there may be good financial or logistical reasons for cutting in July rather than September, so the effect of different times of cutting needs to be considered. Similarly traditional aftermath grazing may be difficult and costly to implement on many sites, so any benefits need to be clearly demonstrated. Local farmers may be persuaded to waive the cost of cutting if there is sufficient quantity of good quality hay, so there may be pressure on managers to apply fertiliser to increase the yield. In the present case, the farmer suggested that since the proposed fertiliser was organic it would be ‘good for the wildflowers’. Any adverse effect of organic fertiliser on wildflowers needs to be clearly demonstrated. The Meadow Management Demonstration was set up to show the effect of these different treatments on the meadow vegetation.

Grime (2000), in a recent report on the future conduct of ecological research, suggested that there needs to be a balance between rigour and realism to encourage studies which embrace greater complexity, but fail to meet the exacting statistical criteria developed and applied to properly replicated reductionist experiments. In the Meadow Management Demonstration, the design was kept deliberately simple to facilitate the application of the different management treatments, and to ensure that site owners and users were able to understand the results. Habitat monitoring techniques were used with permanent quadrats set out on transects, and, although it was pro-active with different management treatments being applied to different areas, there was no randomised replication. So it was not a classical ecological experiment. As a consequence the results required special analysis, and were treated both as the results of an observational study (using Discriminanat Analysis) and as an unreplicated experimental manipulation (using Analysis of Variance). It is recognised that statistical certainty has been traded for realism.

Materials and Methods

Site for Meadow Management Demonstration

The Meadow Management Demonstration was set up at Bedelands Farm in West Sussex in the south of England (National Grid TQ 319204), a Local Nature Reserve of approximately thirty-three hectares on the outskirts of the conurbation of Burgess Hill. The site, which is managed by the local district council and extensively used by dog-walkers, contains a series of moderately species-rich meadows, National Vegetation Classification type *Cynosurus cristatus - Centaurea nigra,* sub-community *Lathyrus pratensis* (MG5a) grassland (Rodwell, 1992) separated by overgrown hedges and areas of ancient woodland. The most uniform of these meadows was selected for the demonstration using TWINSPAN analysis of an initial vegetation survey of all the meadows. This survey consisted of 174 quadrats in six meadows, and twenty-two of the twenty-five quadrats from the selected meadow were sorted into the same group at level three. The selected meadow was arable in 1978, but since 1989 when the site came into public ownership, had been mown annually for hay by a local farmer.

Layout of Demonstration and data collection

The Demonstration compared aftermath grazing with no grazing; a mid July, mid August or mid September hay cut and the twice annual application of organic fertiliser with unfertilised areas.

The two hectare meadow was divided up into thirds in a N/S direction and one third was cut in mid July, one third in mid August and one third in mid September each year. In the orthogonal direction, one half was aftermath grazed by sheep and the other half remained ungrazed. Organic fertiliser (5:5:10 NPK) was applied (at the rate of 80kg ha^{-1}) after the last hay cut and again in spring to a central strip crossing all the other treatments. This rate, consisting of 40kg N $ha^{-1}y^{-1}$, is low compared to MAFF (1997) recommendations of 90kg N $ha^{-1}y^{-1}$ for fields mown for hay.

Fifty-four 2m by 2m permanent quadrats were set out across the field on transects from a baseline so that they could be quickly and easily located each year. Percentage cover was estimated by eye for all the plant species in each quadrat in June before treatments were applied (1997) and again in June for each of the following three years (1998-2000).

Data Analysis

An important aspect of the Demonstration was that visitors to the site, with the help of explanatory display boards, should be able to see for themselves the effect of different treatments on the wildflowers of the meadow. However, since future management of the site will be governed by the results, the effect of the treatments also needed to be monitored scientifically and the data subjected to as rigorous an analysis as possible.

The Demonstration is like an experiment in that management has been manipulated so that different areas have received different treatments. However, treatments have not been replicated at random across the meadow since to do so would have made the application of real treatments impossible and the experimental design difficult for site managers and users to understand. The quadrats in each treatment area are not treatment replication, but simply samples from the same treatment unit (Hurlbert, 1984), so vegetation differences cannot be linked unambiguously with treatment. Analysis of Variance can be used, though, to compare the percentage cover of wildflowers in quadrats from the different areas.

Quadrat data were also analysed using discriminant analysis (SPSS Professional Statistics 6.1) to see how easily quadrats from the different treatment areas could be separated out on the basis of their species composition. If species composition relates to treatment, separation should be difficult to start with and become progressively easier as the treatments take effect.

Discriminant Analysis finds linear combinations of dependent variables (here the percentage cover values for species within each quadrat) which maximise separation between treatment groups, and Wilks'Lambda values indicate how well separated the groups are. A lambda near

1 occurs when within-groups variability is large compared with total variability. Values close to 0 occur when within-groups variability is small compared to total variability. Thus large values of lambda indicate that the species composition of quadrats from different treatments are not different, while small values indicate that the species composition of quadrats from different treatments are different. In order to arrive at a good model, a variety of potentially useful variables, in this case species, are included in the data set. It is not known in advance which of these species is going to be important for the group separation, but using a step-wise selection algorithm, the species that results in the smallest Wilks' Lambda is selected at each step. Thus "good" predictor species, or discriminant species, are identified. The species with the smallest Wilks Lambda value in the final selection is the major discriminant species, but subsidiary discriminant species are usually used in addition to this species to arrive at the best possible separation. Before treatments are applied we expect large values of lambda which should fall over successive years if the treatment has an effect. Discriminant species can also be expected to change after treatment for areas where the treatment is having an effect.

Results

After three years of aftermath grazing there was a visual difference between the grazed and the ungrazed halves of the meadow with a more colourful display of wildflowers in the grazed half. The fertilised strip was noticeably more grassy, but little difference could be discerned between the strips cut at different times of the year.

Wilks Lambda values derived from discriminant analysis of quadrat data (Figure 1) start off high indicating that separation of quadrats on the basis of their species composition into areas of origin could not be made and then fall for grazing and fertilising treatments as these treatments take effect over the three years and the discrimination becomes easier. Wilks Lambda values remain high for mowtime quadrats indicating that a good discrimination of these quadrats was not possible even after three years of cutting at the different times.

The major discriminant species for grazing and fertiliser treatments, as determined by stepwise selection, changed with time during the study (Figure 2). In contrast the original discriminant species for time of hay cut, *Anthoxanthum odoratum*, is unchanged after three years of treatment.

Analysis of Variance showed that after three years of treatments the percentage cover of wildflowers was significantly higher in quadrats from the grazed area than the ungrazed area ($F_{1,7}$ = 14.86, p = 0.000) and significantly lower in quadrats from the fertilised area than the unfertilised area ($F_{1,7}$ = 15.42, p = 0.000). This has no significance for the treatment effects, but does tell us that the differences in the means from treatment areas are large compared with the quadrat variability. There was no significant difference between quadrats from the areas cut in mid July, mid August and mid September ($F_{1,7}$ = 0.87, p = 0.424). Pre-treatment data showed no significant differences between quadrats from different areas.

Figure 1. Wilks Lambda values derived from discriminant analysis of quadrat data from grazed and ungrazed areas, fertilised and unfertilised areas, and areas with a mid July, mid August or mid September hay cut

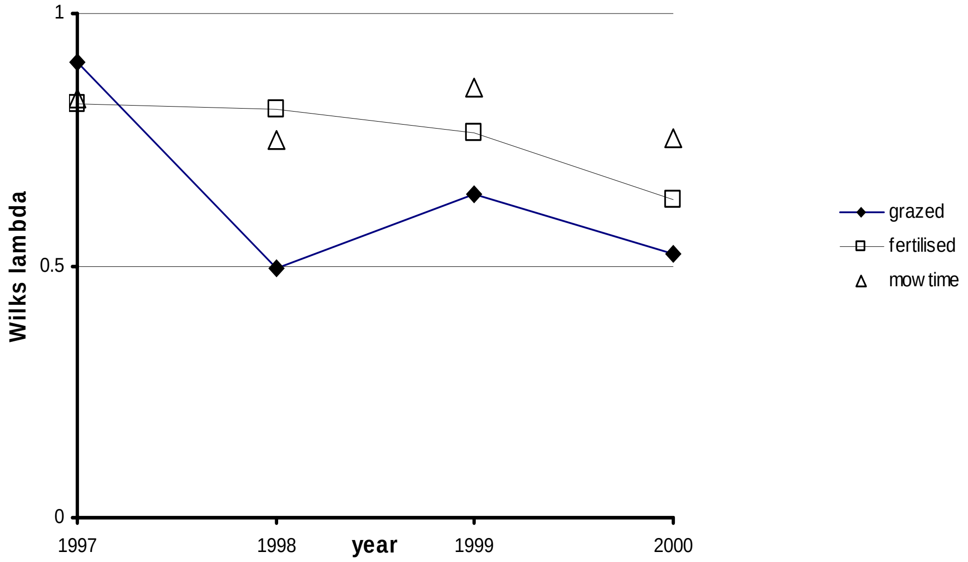

Figure 2. Discriminant Analysis Tables showing changes in species loading over time

[*Major discriminant species* ● *Subsidiary species* □]

A. Grazed / Ungrazed areas

SPECIES	1997	1998	1999	2000
Plantago lanceolata	●			
Holcus lanatus		●		●
Rumex acetosa		x	x	x
Cynosurus cristatus		x		
Anthoxanthum odoratum		x		
Ranunculus acris			●	
Rhinanthus minor				x
Lathyrus pratensis				x

B. Fertilised / Unfertilised areas

SPECIES	1997	1998	1999	2000
Cynosurus cristatus	●			
Anthoxanthum odoratum	x	●		x
Plantago lanceolata			●	●
Lathyrus pratensis		x	x	
Agrostis species				x
Holcus lanatus				x

C. Mid July, mid August and mid September hay cut areas

SPECIES	1997	1998	1999	2000
Anthoxanthum odoratum	●	●		●
Holcus lanatus			●	
Cynosurus cristatus				x
Plantago lanceolata				x

Discussion

Conservation Monitoring

Even with seed sowing modern agriculturally improved swards do not return to traditional species composition quickly on application of traditional management (Smith *et al.*, 2000). The achievement of biodiversity targets for species-rich mesotrophic grassland will depend for now on finding practical ways of managing all the existing areas identified under Agenda 21 initiatives. Successful ecological management, it has been suggested, is likely to become one of the most pressing necessities of our time (Osmerod and Watkinson, 2000). This will require the participation of the general public (DETR, 1997) particularly where, as at Bedelands, the site is extensively used for dog-walking and management options can only be introduced with public approval. For this audience, visual observation of the effect of different treatments on the appearance of the sward is most important.

Most conservation monitoring requires visual observations of this sort to be supported by quadrat data demonstrating in a more objective way that what is seen subjectively does in fact represent reality. In this example we are looking at the visual display of wildflowers which makes the site attractive as an amenity for the local community and also represents a biodiverse example of this sort of grassland. So for conservation monitoring it would be appropriate to look at the overall percentage cover of wildflower species in the quadrats. Normally such monitoring would look at one management treatment and check that percentage cover was not decreasing under that management. Targets would be set, usually degradation thresholds below which abundance should not fall. The pro-active conservation monitoring described here allows consideration to be given to other management treatments within the context of the actual site and the practicalities of a particular situation.

Statistical Treatment of Data

The results of Discriminant Analysis of the quadrat data indicate that the vegetation differences which we are looking at in different parts of the meadow relate to our treatments. The Analysis of Variance shows that the percentage cover of wildflowers is significantly higher in areas of the meadow which have been grazed and significantly lower in areas of the meadow which have been fertilised. Here we are looking at gross changes (differences at 0.1% level) and, although ANOVA by itself cannot link treatments to differences, all the evidence taken together strongly suggests that the differences are due to the treatments.

Grazing Treatment

The Meadow Management Demonstration confirms the importance of aftermath grazing in producing a flower-rich sward. For upland meadows NVC type *Anthoxanthemum odoratum – Geranium sylvaticum* MG3 (Rodwell, 1992) cessation of grazing led to reduction in species richness in one year accompanied by a doubling of harvested dry weight (Smith, 1994; Smith and Rushton, 1994). At Bedelands, the meadow had not been aftermath grazed for at least eight years prior to the setting up of the demonstration and it was noticeable that a large amount of thatch had built up over the surface of the soil. Biomass estimations were not made, but after one season of aftermath grazing visual inspection showed that there was much less thatch in the grazed than the ungrazed half and the more colourful display of wildflowers in the grazed half was confirmed by statistical analysis which showed that there was a greater percentage cover of wildflower species in the grazed than the ungrazed half. In addition the practicalities of aftermath grazing on an urban site subject to sporadic vandalism and utilised by dog-walkers had been demonstrated (Pilkington, 2000), so that the council were able to go ahead with a plan to progressively fence and aftermath graze other meadows on the site.

Fertiliser Treatment

Many experiments have been done on the effect of fertiliser on species-rich grassland, but it is important to look at this in conjunction with the effects of grazing and the timing of the hay cut, since the adverse effect of the fertiliser treatment might be offset by appropriate cutting and grazing regimes (Smith, 1994). Actual grazing, rather than a substitute second mowing, may be necessary to produce the bare patches needed for the regeneration of many of the species associated with species-rich grassland (Smith, 1994; Bullock *et al.*,1995; Smith *et al.*, 2002). In the Demonstration the application of fertiliser at a low rate significantly reduced the

% cover of wildflowers across grazed and ungrazed sward and with three cutting times. Similar effects, which were also not mitigated by appropriate cutting and grazing regimes, have been found for other types of species-rich grassland (Smith *et al.*, 2002 for northern hay meadows; Mountford *et al.*, 1993 for meadows on Somerset peat moor). At Bedelands the visible negative effect of the organic fertiliser and the positive effect of the aftermath grazing have provided a convincing demonstration for farmers and landowners at a FWAG (Farming and Wildlife Advisory Group) Open Day and to representatives attending a county council biodiversity group meeting.

Timing of Hay Cut

Over the first three years of the Demonstration there has been no observable benefit to cutting the hay later than mid July. However, this may not be true in the long-term. It has been suggested for Northern hay meadows (Smith and Jones, 1991) that eventually all characteristic species, even long-lived perennials, may be lost from meadows which are regularly cut early and subsequent experiments in this type of grassland (MG3, *Anthoxanthum odoratum – Geranium sylvaticum*, Rodwell, 1992) found that forbs tend to shed seed during June and July (Smith *et al.*, 1996). So a mid July hay cut, even in the south of England, may be too early for some species.

The meadow at Bedelands is *moderately* species-rich so as well as losing species from the early cut we might expect enhancement of species-richness in the later cuts. Experiments, again in the north of England, aimed at increasing the species-richness of relatively species-poor MG6, *Lolium perenne – Cynosurus cristatus* grassland (Rodwell, 1992) found that a July hay cut, with Autumn and Spring grazing and sowing with additional seeds, led to an increase in species-richness after eight years (Smith *et al*, 2000), but development of the seed bank took even longer (Smith *et al.*, 2002). Increase in species over time was episodic rather than regular; a finding supported by Bergh's (1979) twelve year study of hay fields in Holland, which showed that the amount of seed produced varied from year to year. Regeneration from seed and renewal of seed banks may not take place in any one year. This suggests that it may be many years before the effects of the time of hay cut translate into changes in the vegetation of the Bedelands meadow. These studies also highlight the importance of conserving rather than trying to re-create.

Real-life Situations

Actual site demonstrations like the one described here, encompass practical considerations applicable to the site and this may be more important than the greater degree of statistical certainty obtained through more tightly controlled experiments. For example, it is possible that the beneficial effects of a late cut in relation to seed set may be cancelled out by practical difficulties associated with wetter weather later in the year. After the hay is cut it may not be possible to get back on to the site with today's heavy machinery to turn the hay allowing seed to be shaken out into the cut sward, or to pick it up or bale it at the right time. Over the three years of the Demonstration, the early cut usually proceeded according to plan, but there were almost always difficulties with the late cut due to wet weather which prevented turning of the cut sward and its efficient removal. Smith *et al.* (1996) suggest that the restricted working of the grass crop associated with silage making may reduce the quantity of seed that is returned to the soil and that this may lead to a reduction in the population of species which rely on regeneration from seed particularly those which produce a small amount of seed. This means that in practice the late cut may not result in a more flower-rich sward than the earlier cuts.

Clearly, for the management of real sites, such considerations may be as important as precise knowledge about the effect of seed set on vegetation cut efficiently at a late cutting date.

The Meadow Management Demonstration has functioned as a living exhibition, showing the effect of aftermath grazing and fertiliser application on wildflower meadows to site users and managers, and to a wider audience of landowners at open days. Visual evidence has been supported by scientific monitoring of the effect of these management treatments on the composition of the vegetation. This has convinced local people that appropriate management should be implemented on the site in spite of the increased cost. For habitats such as species-rich neutral grassland, where remaining examples occur to a large extent within public open spaces, achievement of biodiversity targets will depend on initiatives such as this.

References

Bergh, J.P. van der (1979) Changes in the composition of mixed populations of grassland species. *The study of vegetation* (Ed. by M.J.A. Werger) pp.59-80. The Hague, W. Junk

Bullock, J.M., Clear Hill, B., Silvertown, J. & Sutton, M. (1995) Gap colonization as a source of grassland community change: effects of gap size and grazing on the rate and mode of colonization by different species. *Oikos,* **72**, 273-282

DETR (1997) *Convention on Biological Diversity. The United Kingdom's first National report.*

Grime, P. (2000) Report on joint meeting of the BES and ESA Orlando, Florida, USA, 10-13 April 2000. *British Ecological Society Bulletin,* **31** (3), pp.14-17

Hurlbert, S.H. (1984) Pseudoreplication and the design of ecological field experiments. *Ecological Monographs,* **54**, pp.187-211.
MAFF (1997) *The digest of agricultural census statistics, U.K.* The Stationary Office, London

Mountford, J.O., Lakani, K.H., and Kirkkham, F.W. (1993) Experimental assessment of the effects of nitrogen addition under haycutting and aftermath grazing on the vegetation of meadows on a Somerset peat moor. *Journal of Applied Ecology,* **30**, 321-332

Osmerod, S.J. and Watkinson, A.R. (2000) The age of applied ecology. *Journal of Applied Ecology,* **37**, 1-2

Pilkington, M. (2000) Experimental aftermath grazing of urban neutral grassland. *Grazing Management.* (Ed. By A.J. Rook & P.D. Penning) Occasional Symposium No. 34, pp.165-166. British Grassland Society, Reading

Rodwell, J.S. (1992) *British Plant Communities, Volume 3. Grasslands and montane communities.* Cambridge University Press, Cambridge

Smith, R.S. and Jones, L. (1991) The phenology of mesotrophic grassland in the Pennine Dales, Northern England: historic hay cutting dates, vegetation variation and plant species phenologies. *Journal of Applied Ecology,* **28**, 42-59

Smith, R.S. (1994) Effects of fertilisers on plant species composition and conservation interest of UK grassland. *Grassland Management for Nature Conservation* (Ed. by R.J. Haggar & S. Peel) pp.64-73. British Grassland Society, Reading

Smith, R.S. & Rushton, S.P. (1994) The effects of grazing management on the vegetation of mesotrophic (meadow) grassland in Northern England. *Journal of Applied Ecology,* **31**, 13-24

Smith, R.S., Pullan, S. and Shiel, R.S. (1996) Seed shed in the making of hay from mesotrophic grassland in a field in Northern England: effects of hay cut date, grazing and fertilizer in a split-split-plot experiment. *Journal of Applied Ecology*, **33**, 833-841

Smith, R.S., Sheil, R.S., Millward, D. and Corkhill, P. (2000) The interactive effects of management on the productivity and plant community structure of an upland meadow: an 8-year field trial. *Journal of Applied Ecology*, **37**, 1029-1043

Smith, R.S., Shiel, D., Millward, P. and Sanderson, R.A. (2002) Soil seed banks and the effects of meadow management on vegetation change in a 10-year meadow management trial. *Journal of Applied Ecology*, **39**, 279-293

Sussex Wildlife Trust (1996) *Vision for the wildlife of Sussex.* Sussex Wildlife Trust, Henfield

Sutherland, W.J. and Hill, D.A. (1995) *Managing Habitats for Conservation.* Cambridge University Press, Cambridge

Vickery, J.A., Tallowin, J.R., Feber, R.E., Asteraki, E.J., Atkinson, P.W., Fuller, R.J. and Brown, V.K. (2001) The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food resources. *Journal of Applied Ecology*, **38**, 647-664

Acknowledgements

The Royal Society is thanked for a COPUS grant for setting up the Demonstration and Mid Sussex District Council for their collaboration.